

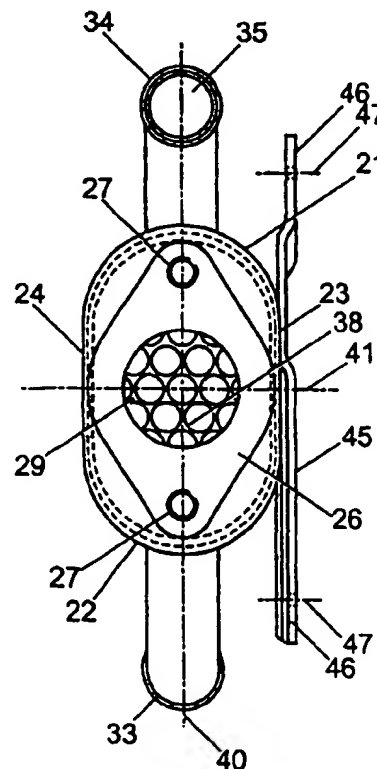


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(54) Title: EXHAUST GAS COOLER**(57) Abstract**

An exhaust gas cooler for reducing the temperature of exhaust gases from internal combustion engines, comprising an external tube (20) extending between two tube plates (30a, 30b) or end walls and defining a coolant chamber (31), coolant inlet and outlet means (33, 34) communicating with the coolant chamber, and a plurality of internal tubes (38) extending between the end walls and arranged to carry the exhaust gas through the coolant chamber. The external tube (20) has a cross-sectional shape which has a height (H) in the major axis which is greater than its width (W) in the minor axis perpendicular to the major axis, preferably oval, or comprising two semi-circles (21, 22) connected by common straight line tangents (23, 24) parallel to the major axis. Such a cross-sectional shape means that the exterior tube (20) has a planar face (23, 24) which simplifies the fitting of mounting brackets and placement within an engine compartment.



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1 **Exhaust Gas Cooler**

2

3 This invention relates to an exhaust gas cooler for
4 reducing the temperature of exhaust gases from internal
5 combustion engines. In particular the invention
6 relates to an exhaust gas cooler in which a coolant is
7 passed around passages through which the exhaust gas
8 travels.

9

10 Figs. 1a to 1c show a known exhaust gas cooler. This
11 prior art cooler comprises a circular tube 1 which has
12 tapered ends 2 which serve as entry 3 and exit 4
13 orifices for exhaust gases. The orifices are provided
14 with flange plates 10 for connection to exhaust pipes.
15 The ends of the tube are sealed by circular tube plates
16 5 which define a coolant chamber inside the tube. Each
17 tube plate 5 has a number of circular holes 6 arranged
18 through it. The holes 6 in each tube plate 5 are
19 connected by a number of small diameter tubes 7 which
20 are sealed at one end to the first tube plate and at
21 the other end to the second tube plate. Exhaust gases
22 flow into the entry orifice 3, along the inside of the
23 small diameter tubes 7 and out of the exit orifice 4.
24 The exterior of the tube is provided with entry and
25 exit nozzles 8, 9 which communicate with the coolant

1 chamber for the supply of coolant liquid. A bracket 11
2 is fixed to the tube for mounting the exhaust gas
3 cooler.

4
5 Similar prior art exhaust gas coolers are known for
6 example from US Patent No 4,685,292. In all the prior
7 art coolers the tubes which carry the exhaust gases are
8 arranged within a cooling chamber of circular cross-
9 section. This results in exhaust gas coolers which are
10 bulky and inefficient in their use of space and do not
11 fit easily within the frequently cramped engine layout.
12 It is an object of the present invention to provide an
13 exhaust gas cooler which is more compact in shape and
14 yet provides flow characteristics comparable or
15 superior to prior art gas coolers.

16
17 According to a first aspect of the present invention
18 there is provided an exhaust gas cooler comprising:
19 an external tube having first and second end walls
20 within said tube, said external tube and end walls
21 defining a coolant chamber between said end walls and
22 first and second exhaust gas chambers outside said
23 first and second end walls respectively,
24 coolant inlet and outlet means communicating with
25 said coolant chamber,
26 a plurality of internal tubes extending from said
27 first end wall to said second end wall and arranged
28 such that the interior of each internal tube
29 communicates with said first and second exhaust gas
30 chambers, and
31 exhaust gas inlet and outlet means communicating
32 with said first and second exhaust gas chambers
33 respectively,
34 wherein the external tube has a cross-sectional shape
35 which has a height in the major axis which is greater
36 than its width in the minor axis perpendicular to the

1 major axis.

2

3 Preferably the cross-sectional shape of the external
4 tube is substantially oval, most preferably it
5 comprises two semi-circles connected by common straight
6 line tangents parallel to the major axis. Such a
7 cross-sectional shape means that the exterior tube has
8 a planar face which simplifies the fitting of mounting
9 brackets and placement within an engine compartment.
10 An oval shape offers advantages over rectangular cross-
11 sectional shapes, since the tube is less prone to
12 cracking, and sharp re-entrant angles in the tube are
13 avoided, reducing stress concentration.

14

15 Preferably the internal tubes are circular in cross-
16 section. It has been found that circular tubes are
17 less prone to clogging with particles carried by the
18 exhaust gases than rectangular tubes, because they do
19 not present internal corners in which particulate
20 matter can collect.

21

22 Preferably the internal tubes are arranged in a
23 hexagonal close packed arrangement, such that each
24 internal tube is spaced by the same spacing from its
25 closest neighbouring internal tubes. Preferably the
26 spacing is less than 2 mm, most preferably less than 1
27 mm. Preferably the spacing is between 10% and 20% of
28 the diameter of the tubes.

29

30 Preferably the exhaust gas cooler is made from
31 stainless steel.

32

33 Preferably each of the exhaust gas inlet and outlet
34 means comprises a flange plate adapted to connect to a
35 corresponding flange plate on a connecting exhaust pipe
36 and having an aperture therein to permit the through

1 flow of exhaust gases. Preferably each of said first
2 and second exhaust gas chambers is further defined by a
3 tapering cylindrical member extending from said
4 aperture to said external tube.

5
6 Preferably the coolant inlet and outlet means comprise
7 tubular pipes adapted to be connected to a coolant
8 hose, most preferably extending substantially in the
9 plane containing the longitudinal axis of the external
10 tube and the major axis of the cross-section of the
11 external tube. Preferably the coolant inlet means is
12 located adjacent to one of the first and second end
13 walls and the coolant outlet means is located adjacent
14 to the other of the first and second end walls.
15 Preferably the coolant inlet and outlet means extend
16 from opposite sides of the external tube.

17
18 Preferably a longitudinally extending portion of the
19 coolant chamber adjacent to each of the coolant inlet
20 and outlet means has no internal tubes extending
21 therethrough, such that it forms a coolant passage
22 having an unobstructed area. This may be achieved by
23 omitting a row of internal tubes from the close-packed
24 arrangement at the top and bottom of the external tube.
25 Preferably the unobstructed area has a minimum
26 transverse dimension greater than the diameter of an
27 internal tube. Preferably the unobstructed area of
28 each passage extends over at least 10% of the internal
29 height of the external tube, most preferably at least
30 15%.

31
32 An embodiment of the invention will now be described,
33 by way of example only, with reference to the
34 accompanying figures, where:

35
36 Figs. 1a, 1b, and 1c are a side elevation, a partial

1 sectional view on line A-A, and an end elevation of a
2 prior art exhaust gas cooler;

3

4 Fig. 2 is a side elevation of an exhaust gas cooler
5 according to a first aspect of the invention;

6

7 Fig. 3 is an end elevation of the device of Fig. 2; and

8

9 Fig. 4 is a sectional view on line B-B of the device of
10 Fig. 2.

11

12 Referring to Figs. 2 to 4 there is shown an exhaust gas
13 cooler according to the invention. The cooler
14 comprises an external cylindrical tube 20 whose cross-
15 section comprises two semi-circular portions 21, 22
16 connected by two tangential portions 23, 24. At each
17 end of the tube are fixed tapered cap portions 25a, 25b
18 which are adapted to fit over the end of the tube and
19 be fastened by suitable means such as welding. At the
20 narrow end of the tapered cap portion 25a, 25b is a
21 flange plate 26 provided with two holes 27 for
22 attachment to a corresponding flange plate (not shown)
23 in order to secure the cooler to an exhaust pipe or
24 line (not shown). The flange plates 26 also each
25 contain a larger hole which serves as entry 28 or exit
26 29 orifices for exhaust gases.

27

28 The ends of the tube 20 are sealed internally by two
29 oval tube plates 30a, 30b, whose shape corresponds to
30 the internal profile of the tube 20. The volume
31 bounded by the tube 20 and plates 30a, 30b forms a
32 coolant chamber 31 inside the tube. Each volume
33 bounded by the tube cap 25a, 25b and the respective
34 plate 30a, 30b forms an exhaust gas chamber 39a, 39b
35 outside the coolant chamber 31 inside the tube. Each
36 tube plate 30a, 30b has 37 circular holes 32 arranged

1 through it. The holes 32 are arranged in a close
2 hexagonal packing (CHP) pattern as shown in Fig. 4 in 9
3 rows of 3, 4 or 5 holes. The holes 32 in each tube
4 plate 30a, 30b are connected by 37 small diameter tubes
5 38 which are sealed at one end to the first tube plate
6 30a and at the other end to the second tube plate 30b.

7
8 It has been found that a CHP pattern maximises the flow
9 efficiency, while the particular arrangement of Fig. 4,
10 in which the three principal axes are arranged
11 perpendicular to and at 30° to the major axis 40 of the
12 tube 20 provides an optimum means of packing the
13 interior tubes within the exterior tube.

14
15 Exhaust gases flow into the entry orifice 28, along the
16 inside of the small diameter tubes 38 and out of the
17 exit orifice 29. The tubes 38 have a diameter of
18 between 5 and 8 mm, usually about 6.5 mm. The spacing
19 between the tubes is about 1 mm or less, so the tube
20 plate 30a does not present a significant obstruction to
21 flow of the exhaust gases.

22
23 Arranged at a first end of the exterior tube is a
24 cooling water inlet pipe 33 whose longitudinal axis is
25 in the same plane as the longitudinal axis 50 and the
26 major axis 40 of the exterior cylinder 20. In this way
27 the hose connections (not shown) will not extend
28 outside the envelope defined by the width W of the
29 exterior tube 20. Similarly at the second end of the
30 exterior tube 20 is a cooling water outlet pipe 34
31 whose axis is in the same plane as that of the inlet
32 pipe 33. The inlet and outlet pipes 33, 34 each
33 communicate with the coolant chamber 31 for the supply
34 of coolant liquid. As coolant passes from the inlet 33
35 to the outlet 34 and exhaust gases pass along the small
36 diameter tubes 38, heat transfer takes place from the

1 exhaust gas via the surfaces of the small diameter
2 tubes 38 to the cooling water.

3
4 The inlet 33 and outlet 34 join the exterior tube at
5 opposite ends of the tube. In the embodiment
6 illustrated both the inlet and outlet pipes 33, 34
7 incorporate a 90° bend, so that the hose connections to
8 the ends 35 of the pipes 33, 34 may be made parallel to
9 the longitudinal axis 50 of the tube. It is to be
10 understood that either of the inlet or outlet pipes 33,
11 34 may be straight so that the hose connections to the
12 ends 35 may be made perpendicular to the longitudinal
13 axis 50 of the tube, or that either of the inlet or
14 outlet pipes 33, 34 may incorporate a bend of an
15 intermediate angle less than 90°. Either of the inlet
16 or outlet pipes 33, 34 may be reversed so that the open
17 end 35 faces towards the centre of the exhaust gas
18 cooler, instead of facing away from the centre of the
19 exhaust gas cooler as shown in Fig. 2.

20
21 A mounting plate 45 is provided on one side of the
22 exhaust gas cooler, to enable the cooler to be secured
23 within an engine compartment. In the embodiment shown
24 the mounting plate has three leg portions 46 formed by
25 double bending of the plate. These serve to space the
26 exhaust gas cooler from the surface to which it is
27 mounted. Each leg portion 46 has a mounting hole 47
28 for a bolt or similar fastener.

29
30 The oval shape of the apparatus enables the exhaust gas
31 cooler of the invention to fit into much tighter spaces
32 in the engine compartment than prior art coolers, while
33 maintaining the benefits of closely packed tubes
34 forming the cooling core. The layout of the tubes in
35 the cooler according to the invention is novel while
36 still maximising the efficiency of the gas and coolant

1 flow. The cooler is highly resistant to corrosion due
2 to its stainless steel construction, and very robust
3 due to the absence of sharp corners on the exterior
4 tube. The flow patterns achieved in testing have shown
5 that the arrangement provides a high resistance to
6 clogging from soot particles.

7
8 Although the invention shows a close packing
9 arrangement with 37 tubes, giving the same flow area as
10 prior art tubes, it is to be understood that other
11 arrangements are possible. For example additional rows
12 of tubes can be added, increasing the height H, without
13 increasing the width W of the exterior tube 20. In a
14 particular embodiment the top and bottom rows 60, 61 of
15 tubes may be omitted, which in effect provides enlarged
16 passages 62, 63 for coolant water at the top and bottom
17 of the coolant chamber. This arrangement has been
18 found to provide particularly advantageous flow
19 characteristics and exhaust gas cooler performance.

20
21 These and other modifications and improvements can be
22 incorporated without departing from the scope of the
23 invention.

1 CLAIMS

2

3 1. An exhaust gas cooler comprising:
4 an external tube (20) having first and second end
5 walls (30a, 30b) within said tube, said external tube
6 and end walls defining a coolant chamber (31) between
7 said end walls and first and second exhaust gas
8 chambers (39a, 39b) outside said first and second end
9 walls (30a, 30b) respectively,

10 coolant inlet (33) and outlet (34) means
11 communicating with said coolant chamber (31),
12 a plurality of internal tubes (38) extending from
13 said first end wall (30) to said second end wall (30)
14 and arranged such that the interior of each internal
15 tube (38) communicates with said first and second
16 exhaust gas chambers (39a, 39b), and

17 exhaust gas inlet and outlet means (28, 29)
18 communicating with said first and second exhaust gas
19 chambers (39a, 39b) respectively,
20 wherein the external tube (20) has a cross-sectional
21 shape which has a height (H) in the major axis (40)
22 which is greater than its width (W) in the minor axis
23 (41) perpendicular to the major axis.

24

25 2. An exhaust gas cooler according to Claim 1,
26 wherein the cross-sectional shape of the external tube
27 (20) is substantially oval.

28

29 3. An exhaust gas cooler according to Claim 1,
30 wherein the cross-sectional shape of the external tube
31 (20) comprises two semi-circles (21, 22) connected by
32 common straight line tangents (23, 24) parallel to the
33 major axis (40).

34

35 4. An exhaust gas cooler according to any preceding
36 claim, wherein the internal tubes (38) are circular in

1 cross-section.

2

3 5. An exhaust gas cooler according to any preceding
4 claim, wherein the internal tubes (38) are arranged in
5 a hexagonal close packed arrangement, such that each
6 internal tube (38) is spaced by the same spacing from
7 its closest neighbouring internal tubes.

8

9 6. An exhaust gas cooler according to claim 5,
10 wherein the spacing between adjacent internal tubes
11 (38) is less than 2 mm.

12

13 7. An exhaust gas cooler according to claim 5 or 6,
14 wherein the spacing between adjacent internal tubes
15 (38) is between 10% and 20% of the diameter of the
16 tubes.

17

18 8. An exhaust gas cooler according to any preceding
19 claim, wherein the exhaust gas cooler is made from
20 stainless steel.

21

22 9. An exhaust gas cooler according to any preceding
23 claim, wherein each of the exhaust gas inlet (28) and
24 outlet (29) means comprises a flange plate (26) adapted
25 to connect to a corresponding flange plate on a
26 connecting exhaust pipe and having an aperture therein
27 to permit the through flow of exhaust gases.

28

29 10. An exhaust gas cooler according to any preceding
30 claim, wherein the coolant inlet (33) and outlet (34)
31 means comprise tubular pipes adapted to be connected to
32 a coolant hose and extending substantially in the plane
33 containing the longitudinal axis (50) of the external
34 tube and the major axis (40) of the cross-section of
35 the external tube.

36

1 11. An exhaust gas cooler according to Claim 10,
2 wherein the coolant inlet means (33) is located
3 adjacent to one of the first and second end walls (30a,
4 30b) and the coolant outlet means (34) is located
5 adjacent to the other of the first and second end walls
6 (30a, 30b).
7

8 12. An exhaust gas cooler according to Claim 10 or 11,
9 wherein the coolant inlet means (33) is located at one
10 side of the external tube (2) on the major axis (40)
11 and the coolant outlet means (33) is located on the
12 diametrically opposite side of the external tube (2) on
13 the major axis (40).
14

15 13. An exhaust gas cooler according to any preceding
16 claim, wherein each of said first and second exhaust
17 gas chambers (39a, 39b) is further defined by a
18 tapering cylindrical member (25) extending from said
19 aperture to said external tube.
20

21 14. An exhaust gas cooler according to any preceding
22 claim, wherein a longitudinally extending portion of
23 the coolant chamber (31) adjacent to the coolant inlet
24 means (33) has no internal tubes (38) extending
25 therethrough, such that it forms a coolant passage (63)
26 having an unobstructed area.
27

28 15. An exhaust gas cooler according to any preceding
29 claim, wherein a longitudinally extending portion of
30 the coolant chamber (31) adjacent to the coolant outlet
31 means (34) has no internal tubes (38) extending
32 therethrough, such that it forms a coolant passage (62)
33 having an unobstructed area.
34

35 16. An exhaust gas cooler according to claim 14 or 15,
36 wherein the unobstructed area has a minimum transverse

- 1 dimension greater than the diameter of an internal tube
- 2 (38).

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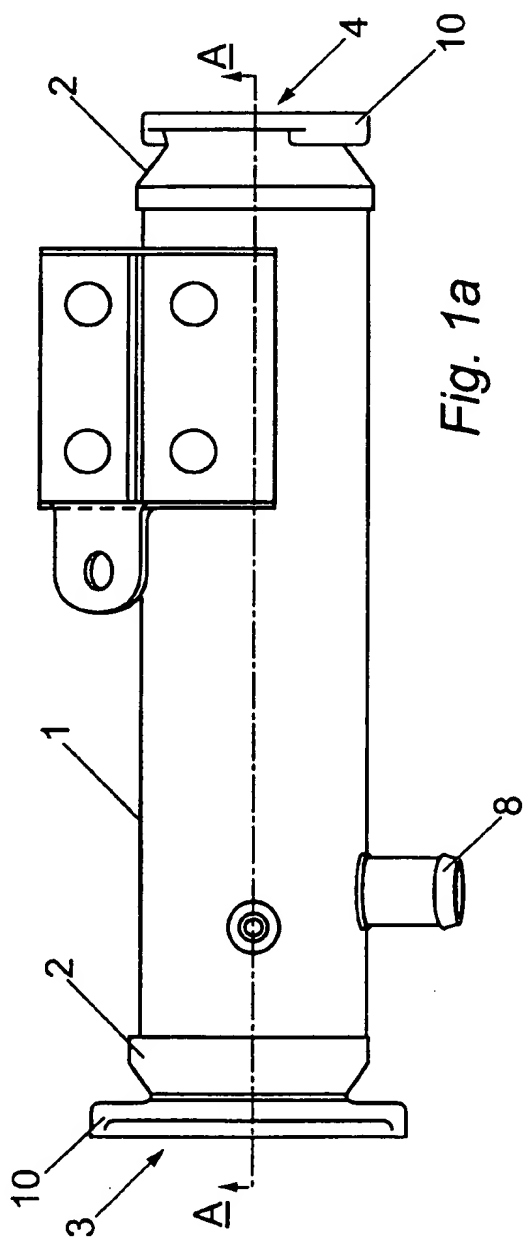


Fig. 1a

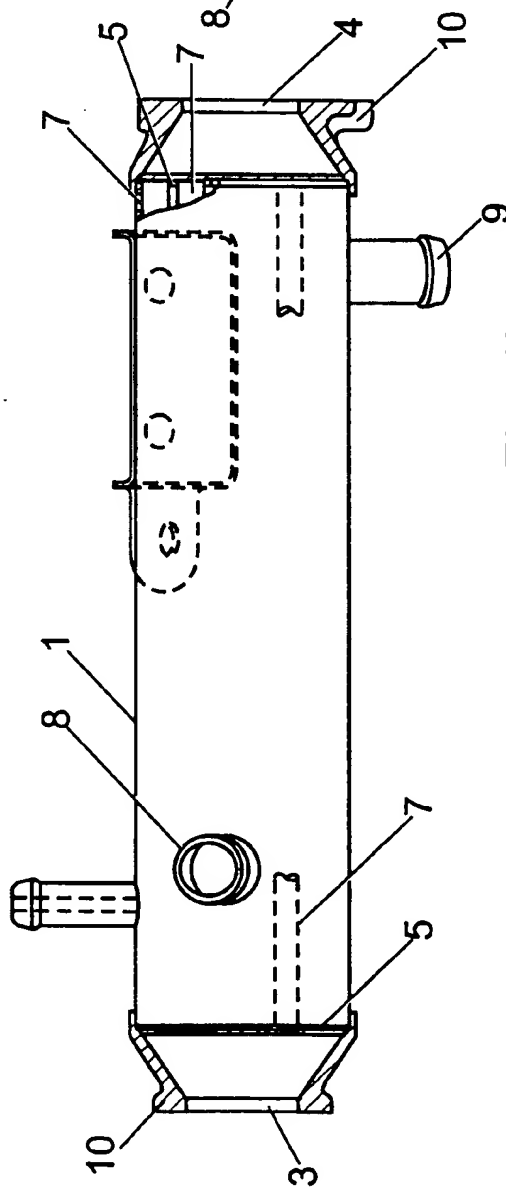


Fig. 1b

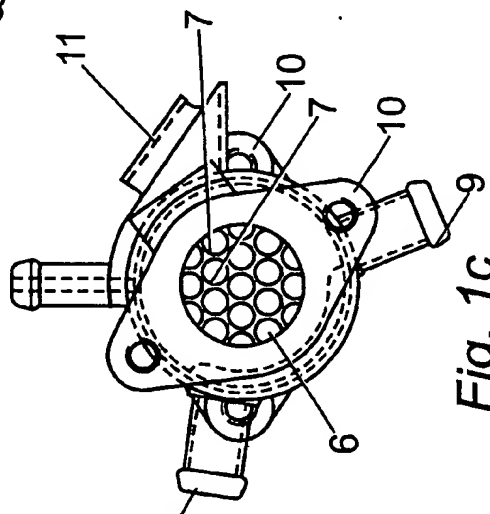


Fig. 1c

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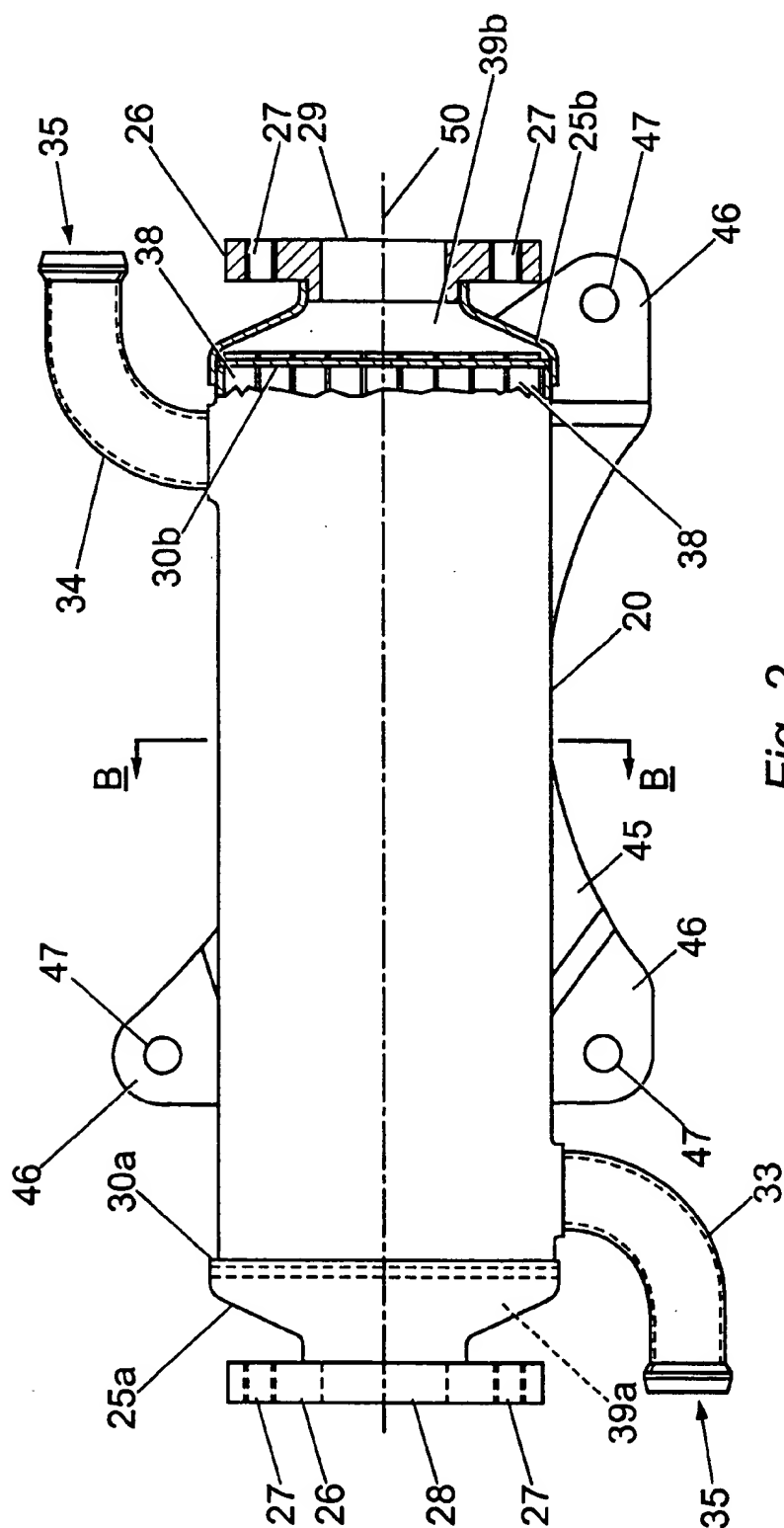


Fig. 2

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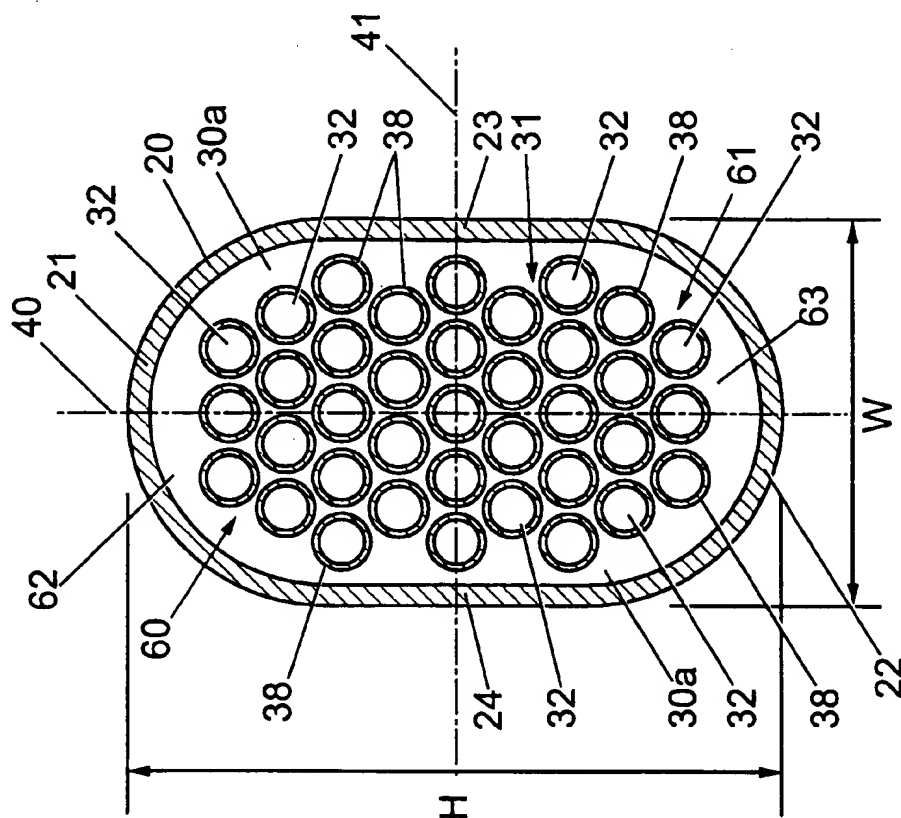


Fig. 4

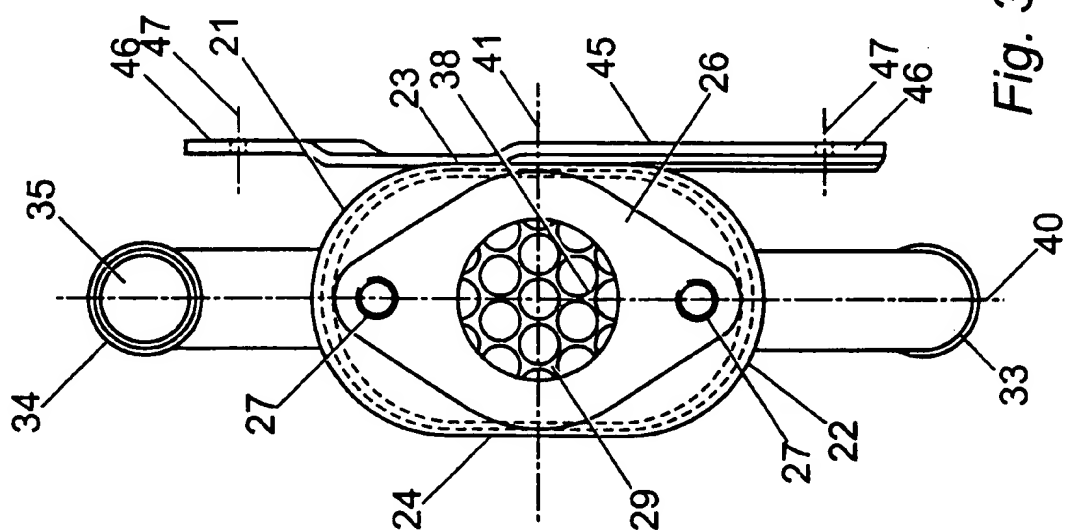


Fig. 3